

Orientation effects in bipolar nebulae: Can disks do it?

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Abstract.

In this work we investigate how a circumstellar disk affects the radiation emitted by an embedded star. We show correlations obtained from broad-band observations of bipolar nebulae indicating that an orientation effect is at play in these systems. The FIR radiation relative to total radiation increases with inclination while the NIR and BVR fractions decrease. This is an expected effect if we consider the system as being made up of a dense dusty disk being irradiated by a hot star. We calculate 2-D models to try and reproduce the observed behavior with different disk and star configurations.

1. Observations

We collected a sample of bipolar planetary nebula and symbiotic nebula from the literature that contained sufficient data to produce a reasonable spectral energy distribution (SED). After constructing the SEDs we compared the luminosity emitted in each band relative to the total luminosity as a function of inclination angle. The inclination angles were determined by the three authors independently, being in agreement within 10-15° for nearly all objects, with an exceptional 30° difference in a couple of cases. In Figure 1 we show the plot with the relative luminosities for each band as a function of the inclination. One can clearly see the increase in the relative FIR flux as well as the decrease of JHK and BVR with increasing inclination.

2. Model

In an attempt to explain this observed behavior, we propose that the systems are composed of a dusty disk being irradiated by a star or binary. This radiation heats up the dust that is responsible for the radiation emitted in the FIR. The combined effect of this re-radiation with the extinction produced by the disk is what would create the observed effect.

We use a simple 2-D radiative transfer model that calculates the temperature of the grains of a disk defined within a square grid. By requiring conser-

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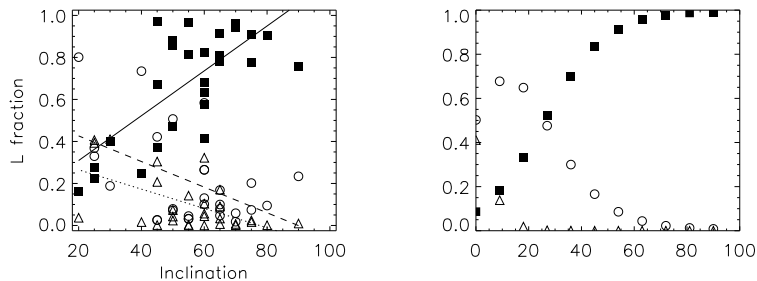


Figure 1. Observed and model (for one system only) correlation between fractional luminosities and inclination angle.

vation of luminosity and iterating we determine the temperature of the dust in each cell. Secondary radiation is not yet accounted for.

For the dust characteristics we adopt typical interstellar grains with $R_v = 3.1$ with properties as calculated by Li & Draine (2001) and a gas to dust ratio of 125. For the disk we obtained temperature maps from which we calculated a random sample of star-disk systems with $\sin(i)$ distributed random inclination angles. This simple method assumes a general temperature, taken here as the average temperature obtained from the 2-D code. We also obtain attenuation functions from the 2-D code that will be used to calculate the extinction of the starlight when intercepted by the disk. Also from the code we obtain the amount of starlight absorbed by the disk. For this component, we assume that the energy is re-radiated in the FIR as a blackbody with the average temperature mentioned before. Figure 1 shows one example of such a model run.

3. Conclusions

The results show that a disk with sufficient density and size is able to produce the general, observed behavior. It is interesting to note that the simple model did not do well when we considered a double system with a luminous cold star as well as the hot ionizing one. On the other hand, the more precise 2-D code copes well with that binary and in fact needs it to reproduce the observed results. These results are only preliminary and much more detail should be accounted for to be able to pin-point the actual disk structure needed. Even so, we can safely say that, yes, disks can do it!

References

Li, A. & Draine, B.T. 2001 ApJ554, 778